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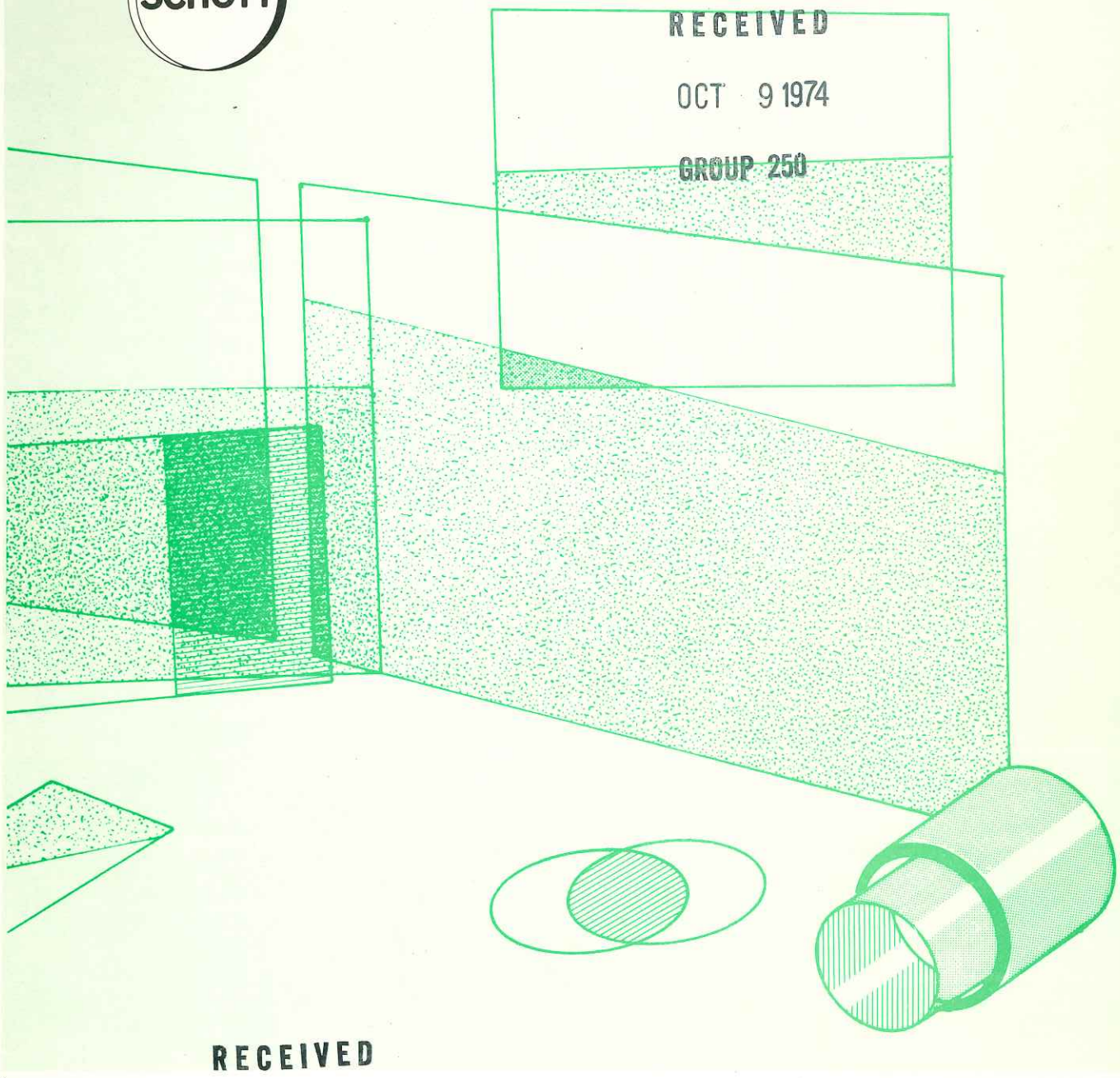

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Thin Film Coatings on Glass

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SCHOTT OPTICAL GLASS, INC., Duryea, Pa. 18642, (717) 457-7485

Thin Film Coatings on Glass

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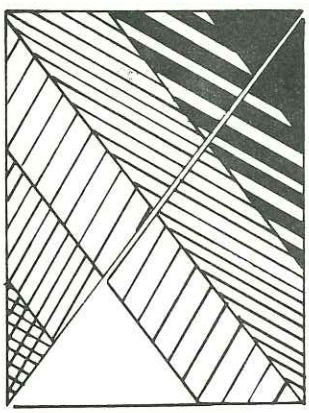
Separate data sheets (nos. 3901 to 3908) give details on the various glasses with thin film coatings according to the groups mentioned below.

Transparent thin films on glass substrates have considerable importance in modern technique as regards control, distribution and modification of radiation in the ultra-violet, visible, and infra-red spectral regions. The applications of today are no longer limited to the field of optical instruments but they are extending more and more to other fields such as lighting and measuring techniques, radiation shielding, control and regulator elements and anti-statics.

For many years, JENA[ER] GLASWERK SCHOTT & GEN. have been involved in the development and industrial production of thin films for various technical and scientific purposes. In addition to the vacuum evaporation method, which is used for the production of monochromatic interference filters *, completely new processes have been developed which are particularly suited for the coating of flat glass–even in large sizes–and for glasses in cylindrical and tubular form. In this process metallic compounds are precipitated from a liquid or gaseous phase onto the substrates and are subsequently transformed under elevated temperatures into highly adhesive surface films consisting mainly of metal oxides or colloids. This technique can also be used for the production of multiple dielectric coatings and therefore different optical and other physical effects can be obtained.

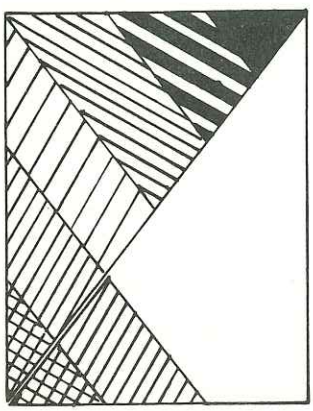
* See leaflet no. 3711-Interference Filters-Special Filters.



1

Heat Reflecting Glasses

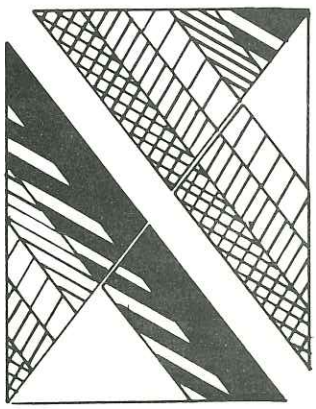
for selective separation of the IR-radiation of light sources to obtain maximum light output.



2

Cold Mirrors

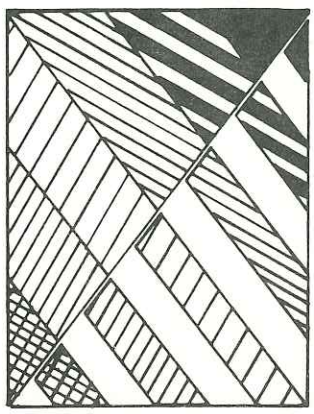
IR-transmitting reflectors, e. g. for projection and operation lamps.



3

Selective Mirrors (Sharp Cut Filters)

Low-loss dichroic filters and UV-mirrors for lighting and optical applications.



4

Achromatic Beam Splitters

for various reflection and transmission ratios.

Optical Properties

The optical properties of the coated glasses mainly result from refraction, absorption and interference of transmitted or reflected radiation in the layers.
As the thickness of the coatings is in the order of a wavelength of light, the superposition of the wave fronts split at the boundaries of partial layers, according to phase relations, leads to an increase or a decrease of the bundle of rays reflected or transmitted in total at the glass surface. Therefore, the construction of layers is designed in such a way that spectral transmittance and reflectance (T or R resp.) meet actual requirements as far as possible.

If not otherwise noted, the curves shown in the diagrams are for normal incidence ($\varphi = 0°$). They characterize the respective filter type with regard to its most important optical properties. In case of oblique incidence of the rays onto the layers the interference conditions always change in such a way that with increasing angle of incidence φ the transmission and reflection ranges shift towards shorter waves ($\lambda_\varphi < \lambda_0$ for $T = \text{const.}$) and, in addition, a more or less pronounced partial polarization of radiation occurs (see types 311 to 314).

Filters and mirrors manufactured by serial production methods may show slight variations from the curves mentioned, but such variations would be below 2 % in all cases of significant functional importance (e.g. the cut location of a filter).

Layer systems giving transmission or reflection curves differing markedly from the standard types as listed can be produced providing they fall within the limits of technical possibilities and subject to minimum quantities which depend on the extent of the development costs involved.

In general the coatings are applied on both sides of the glasses. With plano and slightly bent substrates the layers are applied so uniformly that variations of thickness are smaller than 2 % hithin a surface area of 0.1 m².

Stability of Coatings

The coatings are resistant to wiping, insensitive to water and most acids as well as to organic solvents. Depending on the resistance of the substrate material the coated glasses may be subjected to strong thermal and UV-radiation even for longer periods and heated up to temperatures of 400 to 500 °C. In some cases it is also possible to subject the coated glasses to a thermal toughening process; details are available upon request.

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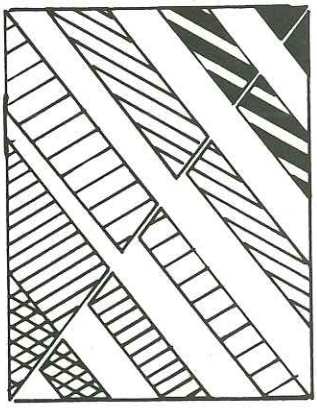
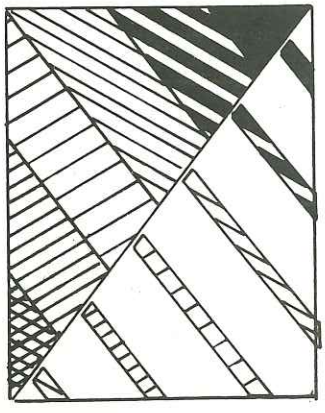


5

Colour Conversion Filters

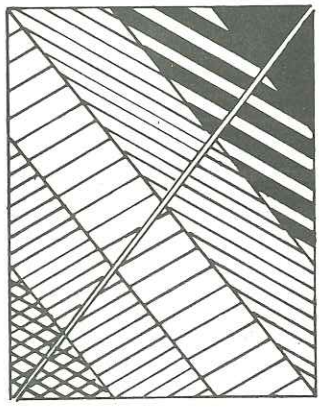
for conversion of the colour temperature of light sources



6

Attenuation Filters

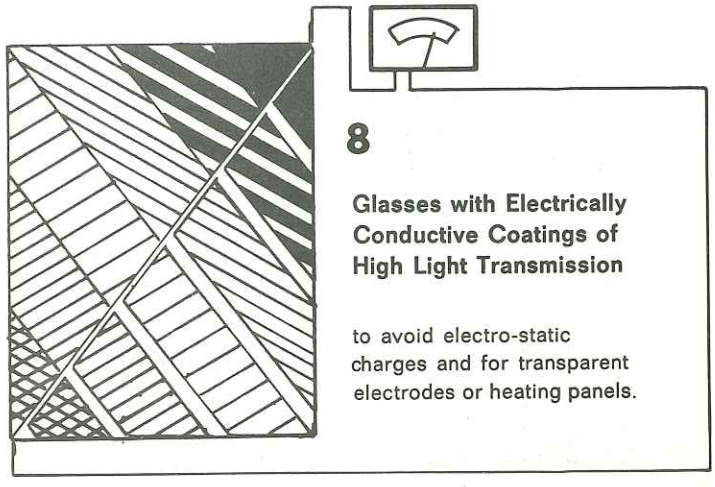
for the protection from UV, bleaching and glaring irradiation



7

Anti-reflection coated Glasses

for glazing of instruments, protection of paintings, etc.



8

Glasses with Electrically Conductive Coatings of High Light Transmission

to avoid electro-static charges and for transparent electrodes or heating panels.

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Thin Film Coatings on Glass

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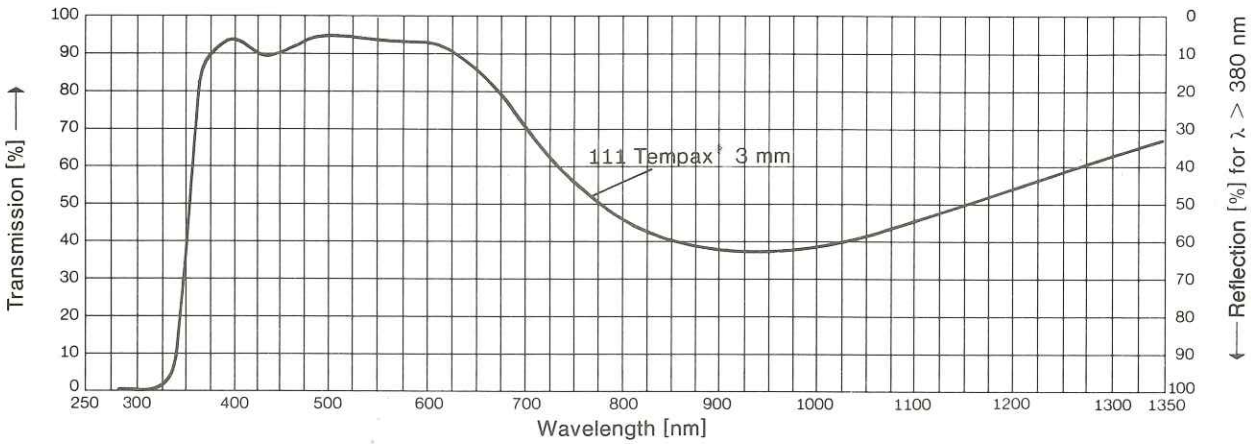
1. Heat Reflecting Glasses

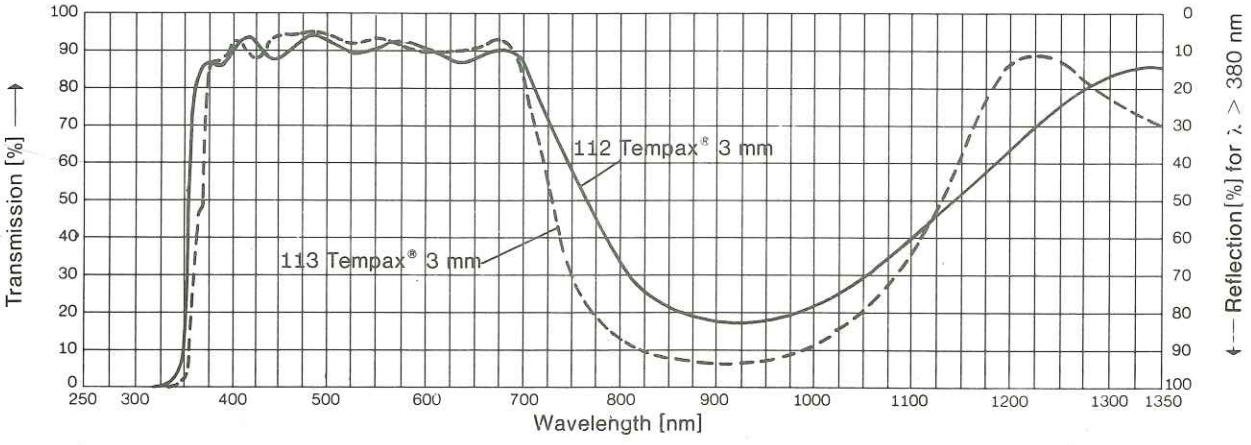
1.1 High Transmission Filters for projectors and irradiation lamps.

Substrates: Tempax®* glass is recommended for energies ≥ 0,2 W/cm².
For types 111 to 116 with almost absorption free glasses the approximation R = 100–T [%] is applicable in the range from λ = 0,38 µm to λ = 2,5 µm.
Applications: Heat resisting filters in high energy lighting systems; filters for the simulation of solar radiation by means of xenon lamps; selective infra-red reflectors.

Type	Main Characteristics or Applications	Spectral Range of T_{min} (R_{max}) [nm]	Substrate	Maximum Size [mm]
111	Wide-band reflection in the near Infra-red	900 . . . 1000	at liberty	see table "Substrates"



112 [formerly T 6]	Strong attenuation of Xenon-IR-radiation (see diagram on page 3)	870 . . . 950	at liberty	see table "Substrates"
113 [formerly T 8]		850 . . . 900	Tempax®* polished	600×400

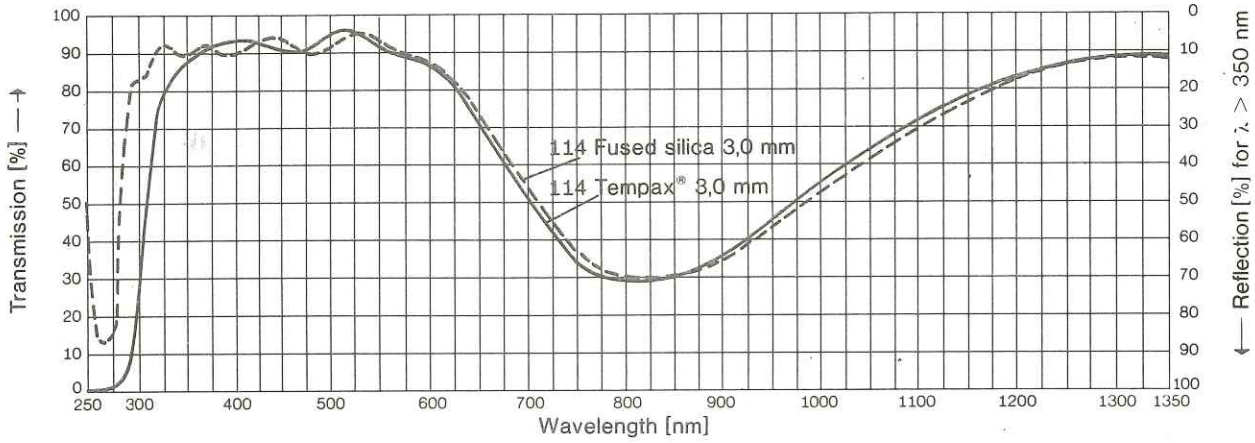


* Tempax® = heat resisting sheet glass, see leaflet no. 8801

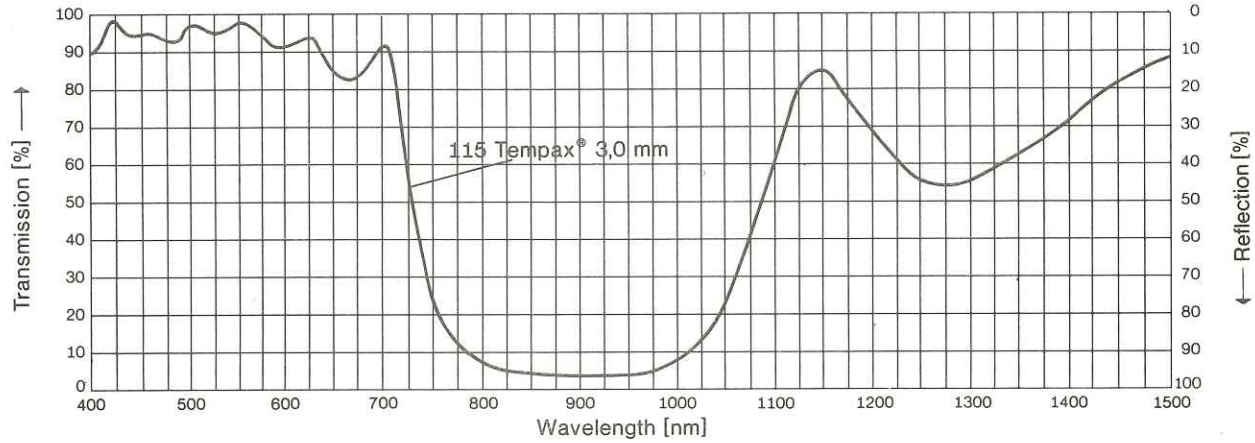
Symbols:

λ	= wavelength	[nm or µm]	T	= transmission	[%]
R	= reflection	[%]	T_{min}	= minimum of T in the λ-range	[%]
R_{max}	= maximum of R in the λ-range as shown	[%]			

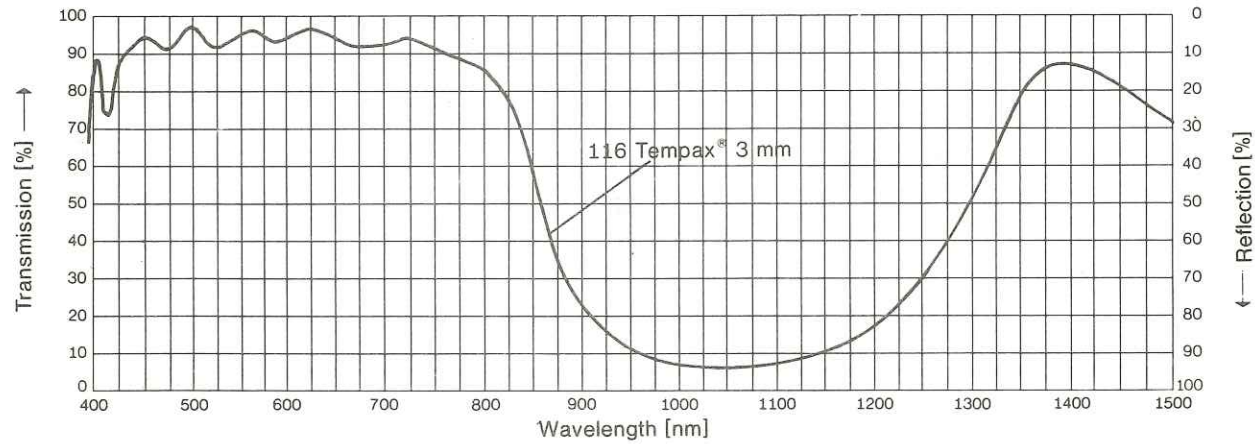
Type	Main Characteristics or Applications	Spectral Range of T_{min} (R_{max}) [nm]	Substrate	Maximum Size [mm]
114	IR-reflection with extended UV-transmission	800 . . . 850	Tempax®* fused silica	600×500



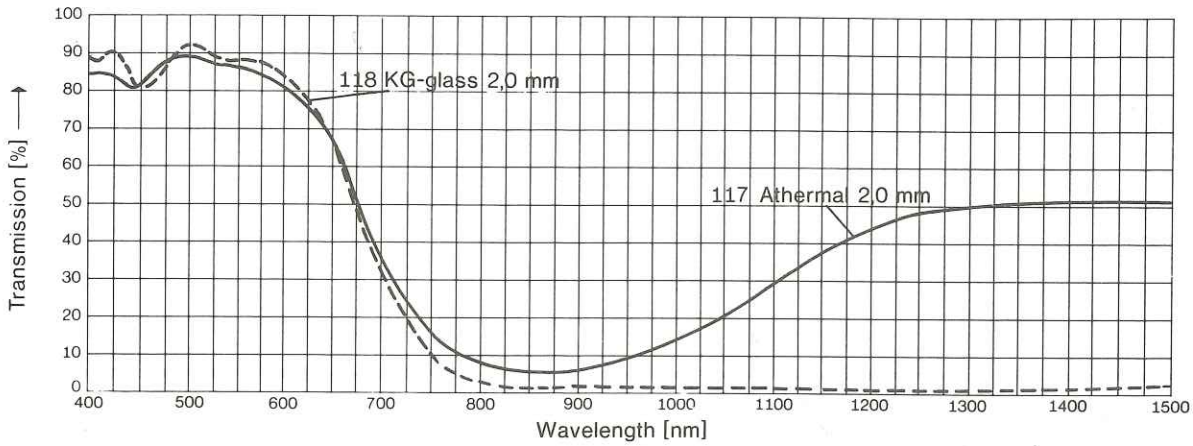
115	Sharp cut blocking filter or reflector for the near infra-red	850 . . . 900	Tempax®*	300×200



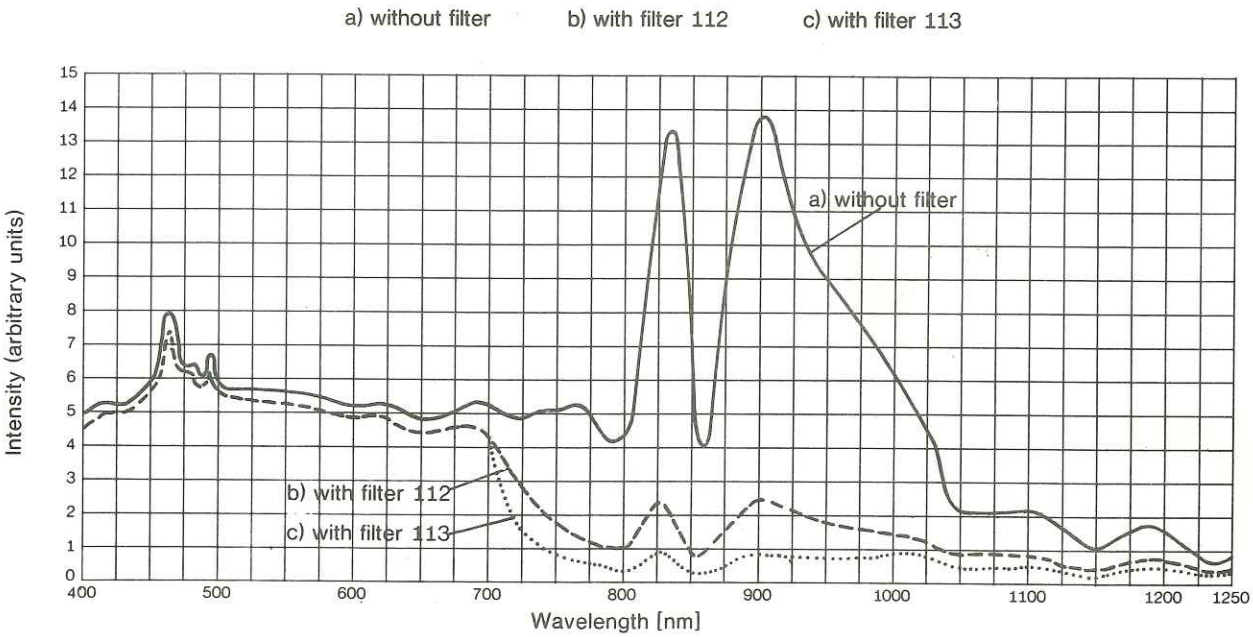
116	Blocking filter or reflector with extended band width in the near infra-red	1000 . . . 1100	Tempax®*	300×200



Type	Main Characteristics or Applications	Spectral Range of $T_{min}(R_{max})$ [nm]	Substrate	Maximum Size [mm]
117	Selective IR-reflection on IR-absorbing sheet glass	850 . . . 900	e. g. athermal 00	500×300
118	Selective IR-reflection on IR-absorbing optical KG-glass	800 . . . 850	KG-glass 1-4 mm thick	150×100



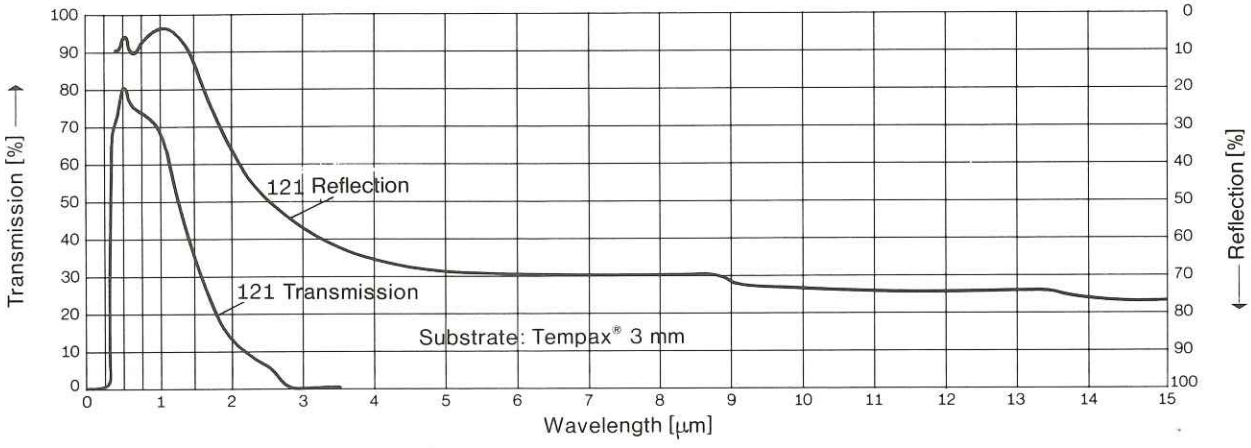
Spectral Emission of Xenon Lamp (XBO 2001)



1.2 Glasses with Increased IR-Reflection

above ~ 2 μm for the shielding of heat radiation and the reduction of thermal emission (see also types 8.2).

Type	Main Characteristics or Applications	Coating	Substrate	Maximum Size [mm]
121	Wide-band reflection	one side	Tempax®*	500×500



* Tempax® = heat reflecting sheet glass, see leaflet no. 8801

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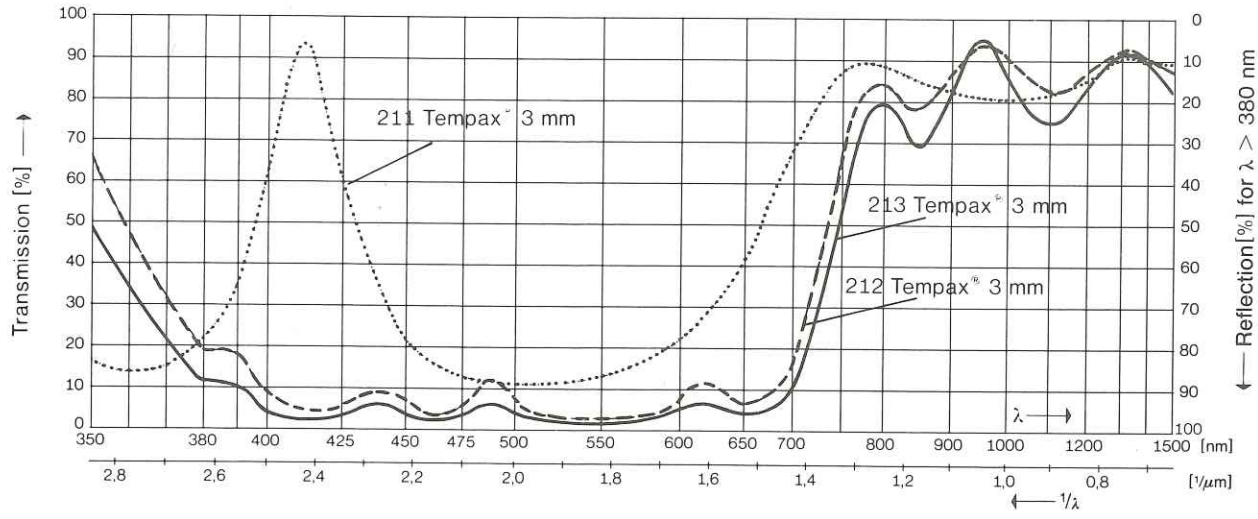
2. Cold Mirrors

All dielectric mirror coatings for high visible light transmission and low infra-red reflection.

Substrates: Preferably Tempax® * glass, also in cylindrical shape.

Applications: Reflectors for projection, operation and dental lamps, irradiation units etc.

Type	Main Characteristics	Coating	Application under $\varphi =$	Max. Dimensions [mm]
211	Simple mirrors with R > 70% from 440 to 630 nm	both sides	0°	see table "Substrates"
212	Achromatic mirrors with R > 85% from 420 to 660 nm	one side	0° to 45°	see table "Substrates"
213	Achromatic mirrors with R > 90% from 420 to 660 nm	both sides	0° to 45°	see table "Substrates"



* Tempax® = heat resisting sheet glass, see leaflet no. 8801

Symbols: R = reflection [%] φ = angle of incidence of radiation with the normal to surface λ = wavelength [nm or µm]

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3. Selective Mirrors (Sharp Cut Filters)

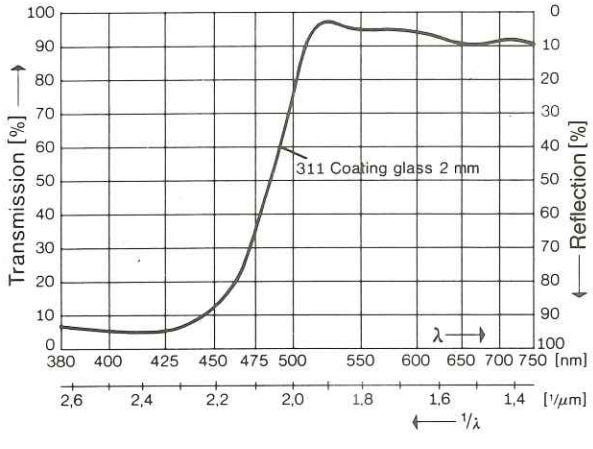
3.1 Dichroic Filters

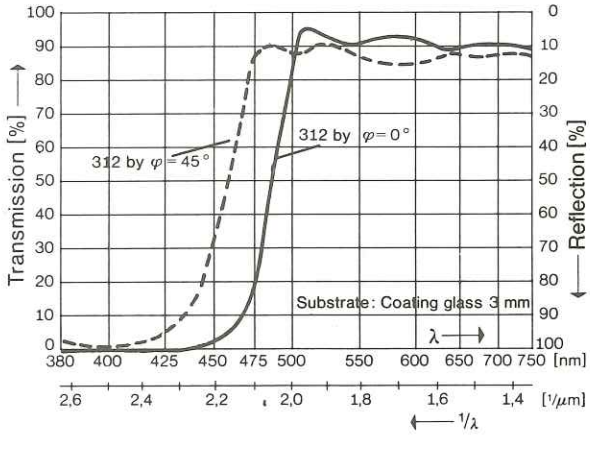
Filters made of all dielectric coatings for the splitting of light bundles into various colours at almoust no loss ($R \approx 100 - T$ [%]. The filter type must be selected according to the angle of incidence ($\varphi = 0°$ or $\varphi = 45°$). The relative shift of wavelength according to the angle of incidence φ is shown in the diagram on page 2.

Substrates: Coating glass or white plate glass.

Applications: Production of simultaneous colour extracts for colour reproduction; light separation for colour taking instruments and lighting equipment in photo, film and television studios.

Type	Main Characteristics	Coating	Application under $\varphi =$	λ-value for $T = R = 50\%$	Max. Dimensions [mm]
311	blue mirror	one side (rear side anti-reflection coated)	45°	480 . . . 500	400 × 250
312	blue mirror	both sides	0°	480 . . . 500	400 × 250



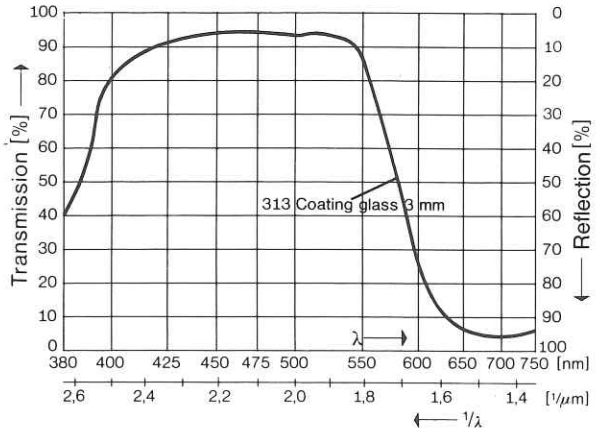


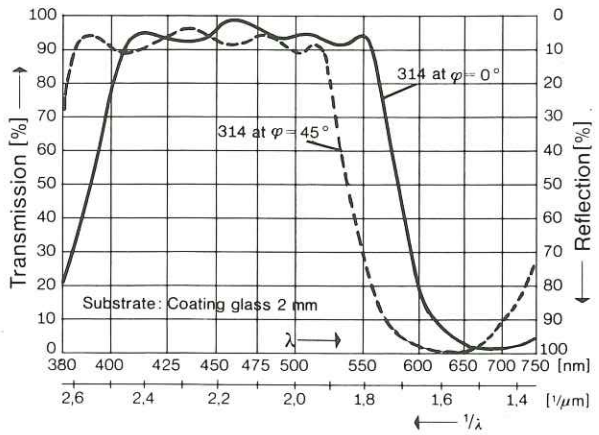
Symbols:

R	= reflection	[%]	
T	= transmission	[%]	
φ	= angle of incidence of radiation with the normal to surface		
λ	= wavelength	[nm or μm]	
λ_0	= wavelength for which T-values at $\varphi = 0°$ are obtained	[nm or μm]	
λ_φ	= wavelength for which T-values at $\varphi =$? are obtained	[nm or μm]	

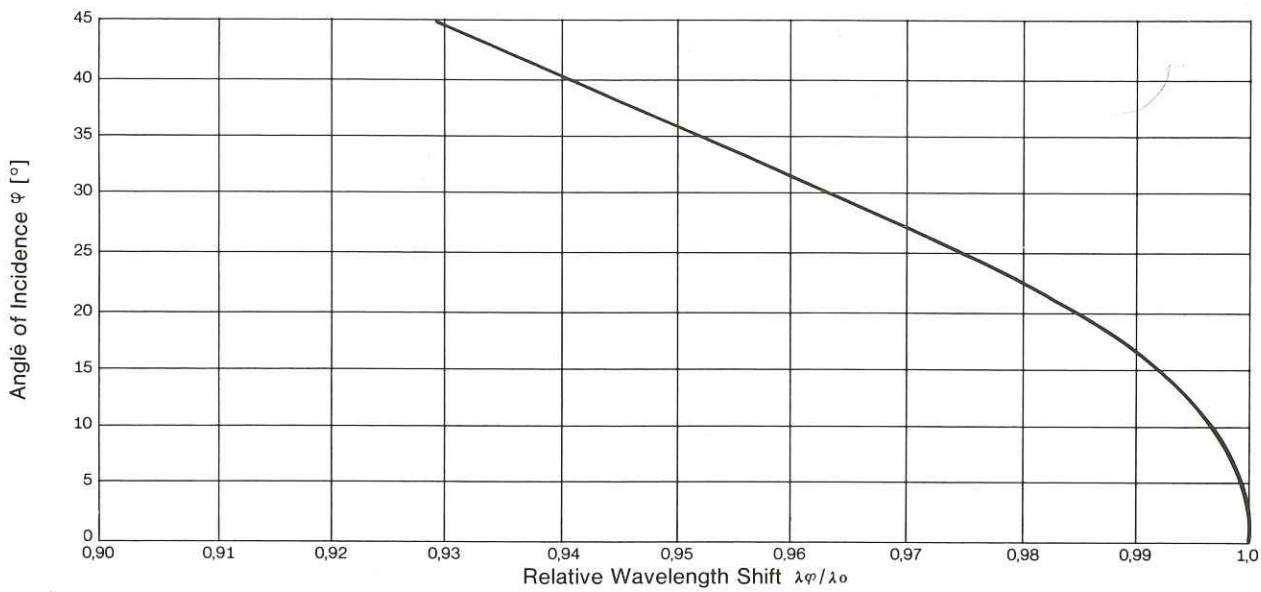
3.1 Dichroic Filters

Type	Main Characteristics	Coating	Application under $\varphi =$	λ-value for $T = R = 50\%$	Max. Dimensions [mm]
313	red mirror	one side (rear side anti-reflection coated)	45°	570 . . . 590	400 × 250
314	red mirror	both sides	0°	570 . . . 590	400 × 250





Relative Wavelength Shift $\lambda\varphi/\lambda_0$ of Cut Location according to Angle of Incidence φ



Example: Cut location at $\varphi = 0°$ and $T = R = 50\%$ is 580 nm (see filter type 314).

How far will the cut location be shifted with an angle of incidence of 30°?

as per the above diagram: at $\varphi = 30°$ ⟶ factor = 0,963

$\lambda\varphi = \lambda_0 \cdot$ factor $\qquad \lambda_0 = 580$ nm

$\lambda\varphi = 580 \cdot 0{,}963 = 558{,}5$ nm $\qquad$ factor = 0,963

The change of $\varphi = 0°$ to $\varphi = 30°$ shifts the cut location from 580 nm to 558,5 nm.

3.2 UV-Mirrors

Transmission filters for the separation of selected UV-regions from radiant energy by means of reflection on multilayer coatings.

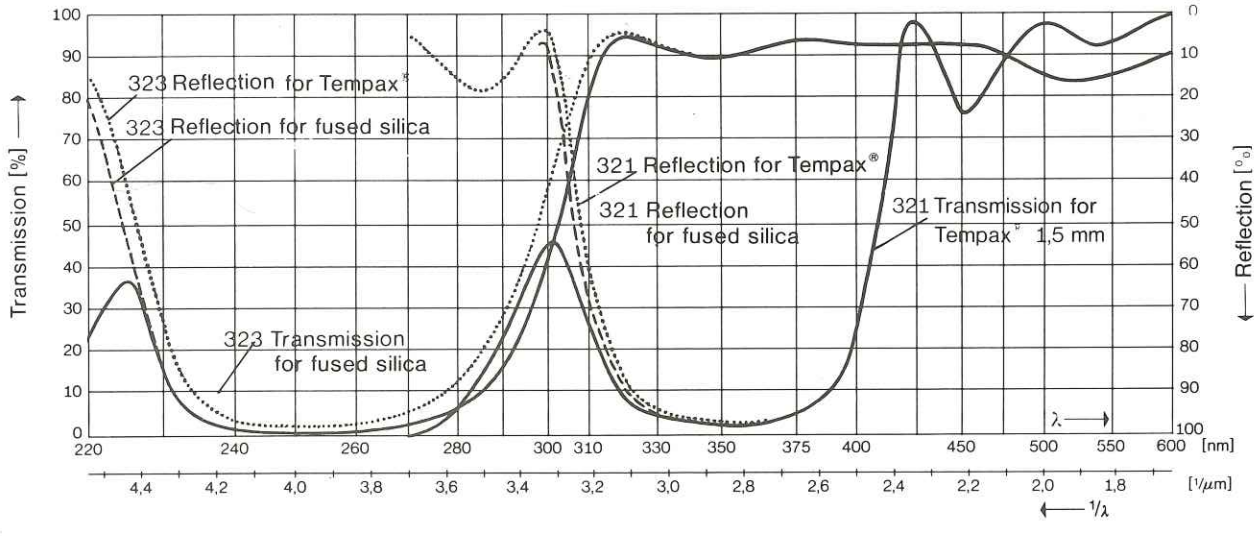
Substrates: Tempax®* glass, polished fused silica.

Applications: Separation of the UV-energy of gas discharge lamps, reflectors for irradiation test instruments, combination with cold mirrors for the simulation of sun radiation.

* Tempax® = heat resisting sheet glass, see leaflet no. 8801

Type	Main Characteristics	Application under $\varphi =$	Max. Dimensions [mm]
321	R ≳ 80% from 320 to 390 nm	0°	500 × 300
322**	R ≳ 80% from 310 to 380 nm	45°	500 × 300
323	R ≳ 90% from 240 to 280 nm	0°	500 × 300

** curve similar to type 321



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3.3 Cylindrical Reflectors

with dielectric multilayer coatings for the irradiation of Laser-materials, see leaflet no. 7519.

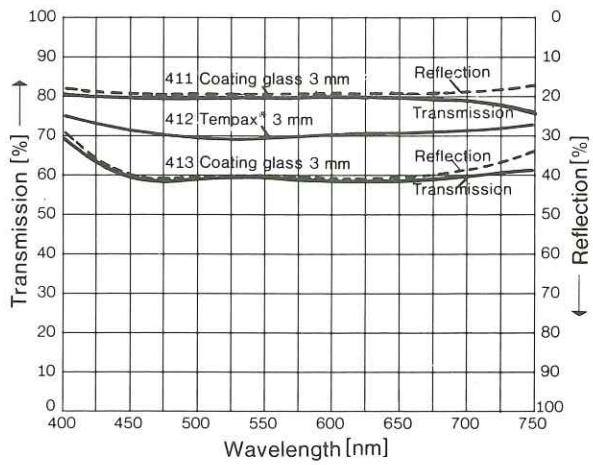
4. Achromatic Beam Splitters

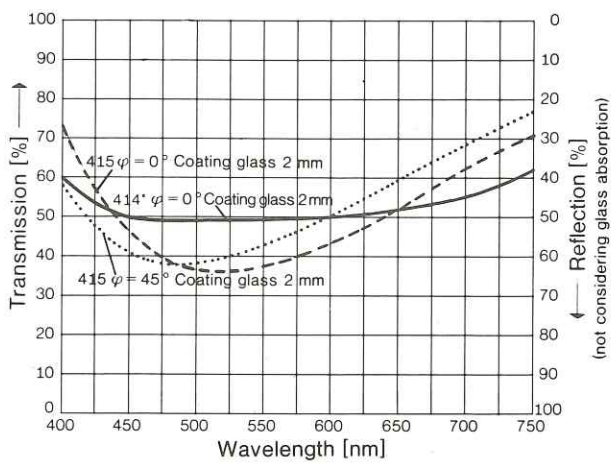
Semi-transparent mirrors predominantly loss free and with low spectral effect on the splitting ratio. Type nos. 416, 417 and 418 coated on both sides are mainly used at $\varphi \cong 0°$, type nos. 411 to 415 (the rear side anti-reflection coated on request) are designed for a preferred use under $\varphi = 45°$. Type no. 418 has an absorption $A = 100 - T - R \approx 30\%$.

Substrates: In general coating glass or white plate glass; maximum sizes see table "Substrates".

Applications: Almost achromatic splitting or assembly of optical beams according to different intensity ratios; spy mirrors for observation chambers.

Type	R_{max} [%]	T_{min} [%]	Application under $\varphi =$	Coating	Max. Dimensions
411	20	80	at liberty	one side	see table Substrates
412	30	70	at liberty	one side	see table Substrates
413	40	60	at liberty	one side	see table Substrates
414	50	50	45°	one side	see table Substrates
415	60	40	45°	one side	see table Substrates



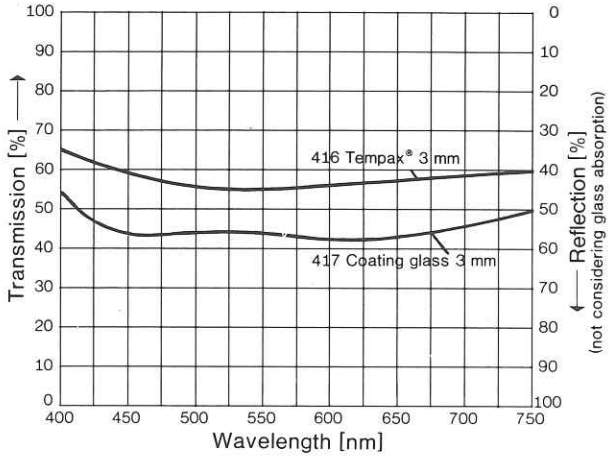

415 φ = 0° Coating glass 2 mm
414* φ = 0° Coating glass 2 mm
415 φ = 45° Coating glass 2 mm
Transmission [%]
Reflection [%]
(not considering glass absorption)
Wavelength [nm]

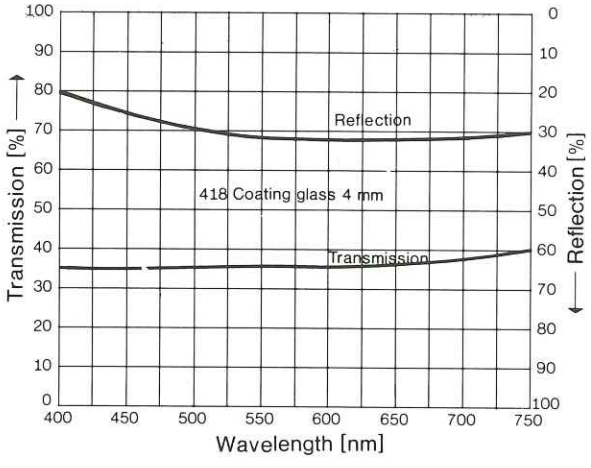
* rear side anti-reflection coated

Symbols:

R = reflection [%]
R_{max} = maximum of R in the wavelength range as shown [%]
T = transmission [%]
T_{min} = minimum of T in the wavelength range as shown [%]
φ = angle of incidence of radiation with the normal to surface

Type	R_{max} [%]	T_{min} [%]	Application under $\varphi =$	Coating	Max. Dimensions
416	45	55	at liberty	both sides	see table Substrates
417	55	45	at liberty	both sides	see table Substrates
418	35	35	at liberty	both sides	see table Substrates





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5. Colour Conversion Filters

for the conversion of the colour temperature of light sources

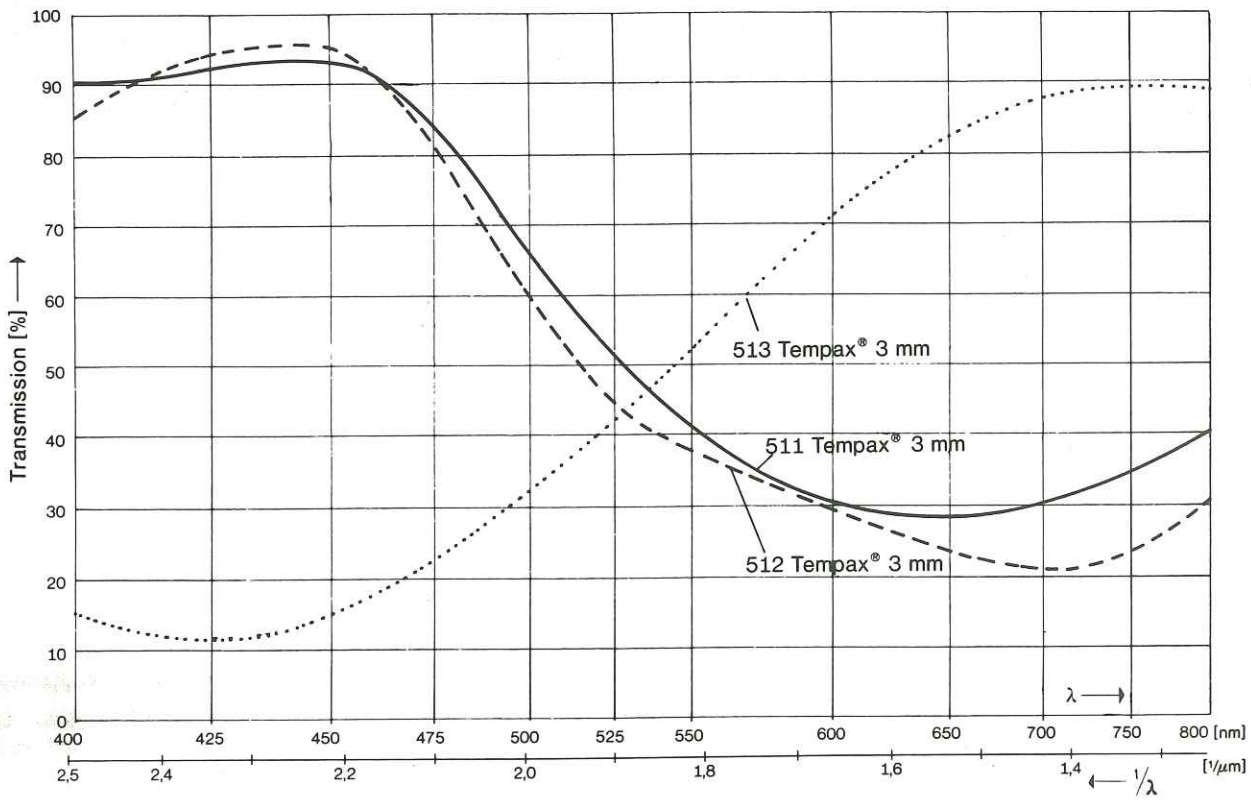
Special dichroic filters, almost absorption free, which separate by reflection the radiation not transmitted.

Substrates: preferably Tempax® glass * which ensures heat resistance of the filters under high intensity radiation.

Applications: filters for lamps in TV, cinema and photostudios and for picture taking equipment.

Type	Conversion of Colour Temperature**	Chromaticity Co-ordinates** x	y	Max. Dimensions mm
511	3200 K to 5600 K ± 200 K	0,330 ± 0,004	0,339 ± 0,015	600 x 400
512	3200 K to 6000 K ± 200 K	0,322 ± 0,004	0,332 ± 0,010	600 x 400
513	6000 K to 3200 K ± 100 K	0,423 ± 0,015	0,398 ± 0,030	600 x 400

Conversion filters for other initial and final temperatures can be produced on request.



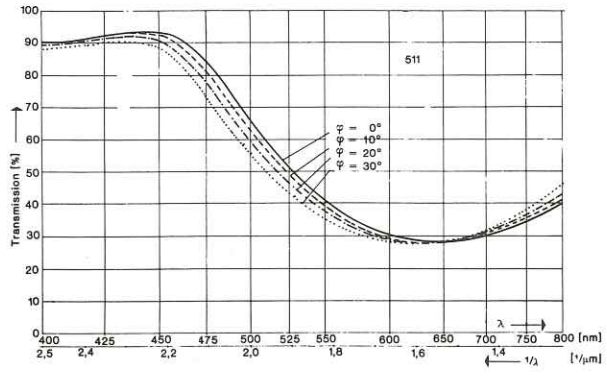
* Tempax glass = heat resistant sheet glass; see leaflet no. 8801

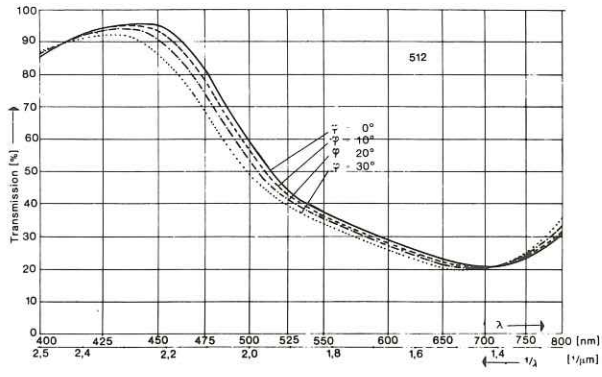
** The chromaticity co-ordinates x and y have been calculated, according to DIN 5033 (German industry standards), from the known spectral energy distribution of a black body of a specified temperature and the measured spectral transmittance of the filter. These chromaticity co-ordinates, according to DIN 5033 page 8, indicate the colour temperature. The diagram on the verso shows the chromaticity co-ordinates of black bodies as a function of temperature.

Symbols: K = degrees Kelvin = unit of color temperature λ = wavelength [nm or µm]

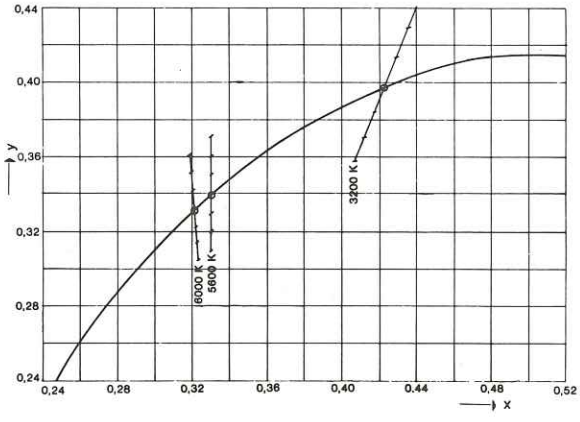
φ = angle of incidence of radiation with the normal to surface

Spectral transmittance and colour temperature as a function of angle of incidence φ.





Type	Colour Temperatures at Various Angles of Incidence			
	φ = 0°	φ = 10°	φ = 20°	φ = 30°
511	3200 K to 5600 K	3200 K to 5570	3200 K to 5520 K	3200 K to 5450 K
512	3200 K to 6000 K	3200 K to 5950	3200 K to 5900 K	3200 K to 5800 K
513	6000 K to 3200 K	6000 K to 3220	6000 K to 3250 K	6000 K to 3300 K



Extract of the chromaticity diagram with Planckian locus of the most similar colour temperature and Judd lines (DIN 5033 page 8)

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6. Attenuation Filters

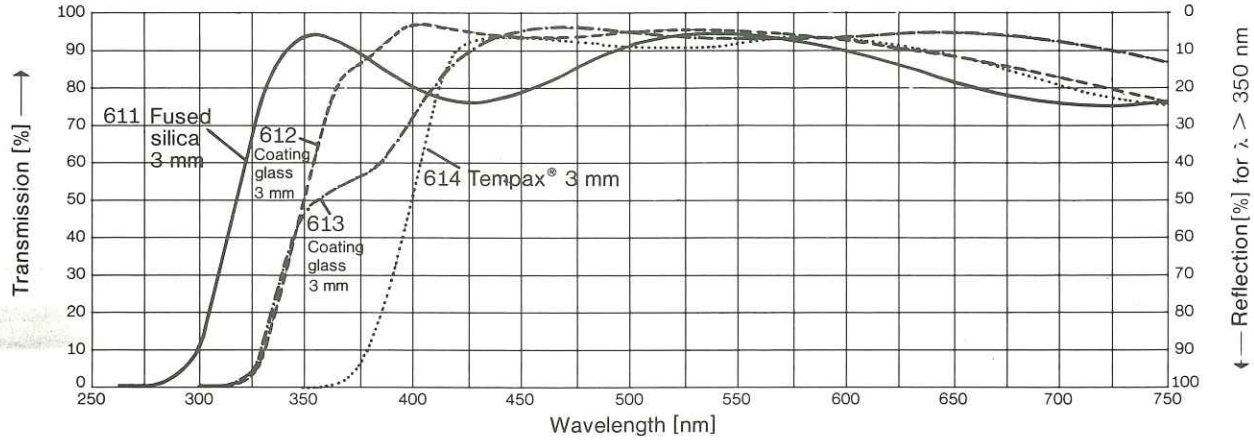
Absorbing coatings for the attenuation or elimination of certain spectral ranges.

6.1 Sharp Cut UV-Filters

characterized by the wavelength of transmission 1%, 10%, 50%.

Applications: Separation of certain UV-ranges of radiation – filters with steeper cut-off curves on request.

Type	λ 1% [nm]	λ 10% [nm]	λ 50% [nm]	Main Characteristics	Substrates	Max. Dimensions [mm]
611	280	300	315	Blocking filter for the UVC range ($\lambda < 280$ nm)	Fused silica	see table "Substrates"
612	320	330	350	Blocking filter for the UVB and UVC ranges ($\lambda < 315$ nm)	at liberty	see table "Substrates"
613	320	330	abt. 355	Blocking filter for the UVB and UVC ranges with attenuation of the UVA range	at liberty	see table "Substrates"
614	360	380	abt. 400	Blocking filter for the almost entire UV region	at liberty	500 × 300

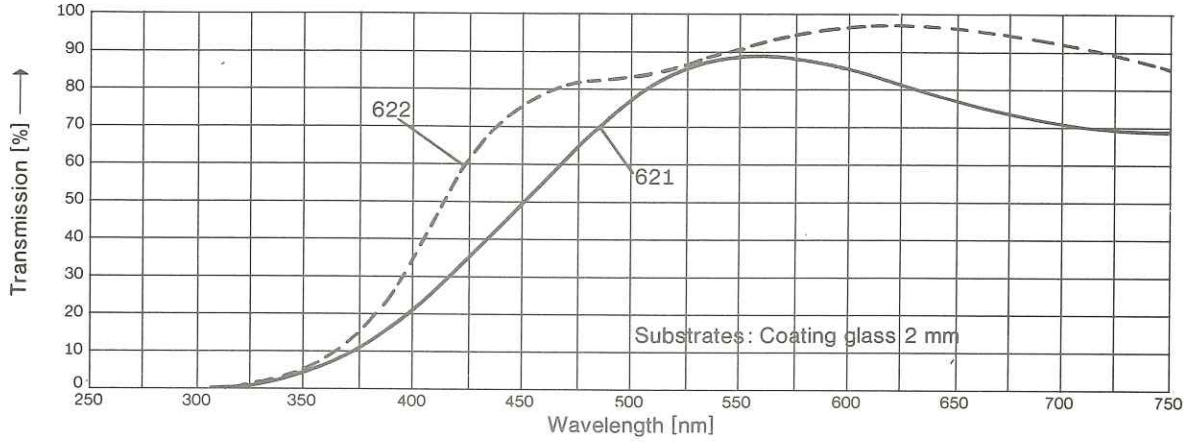


Symbols: λ = wavelength [nm or μm]

6.2 Filters with attenuation gradually decreasing from the UV to the adjacent visible spectral region.

Applications: Coating of flash lamps, light shielding windows.

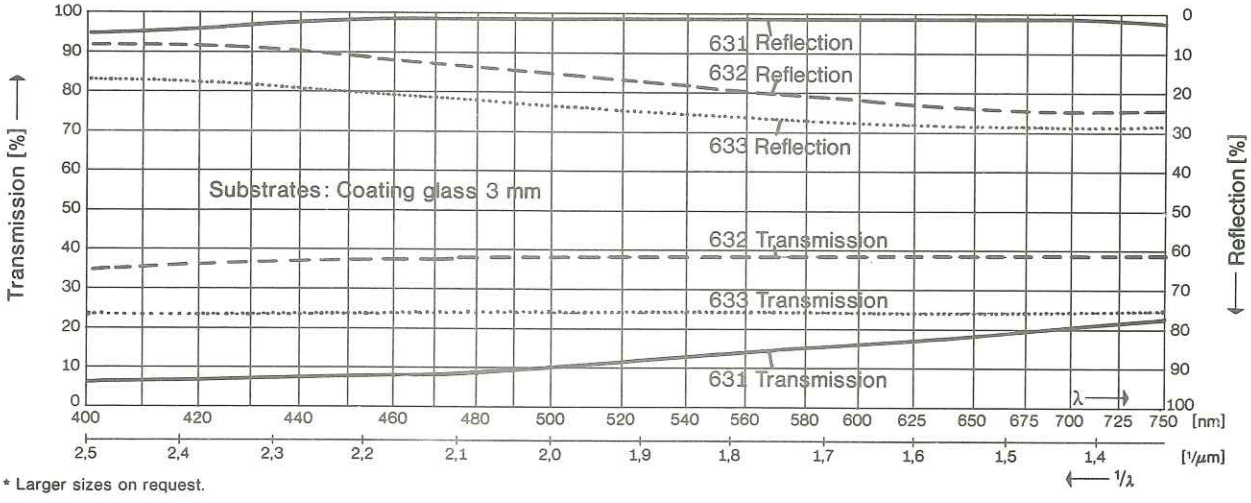
Type	λ 1% [nm]	λ 10% [nm]	λ 50% [nm]	Main Characteristics	Max. Dimensions
621	ca. 330	ca. 375	ca. 450	light yellow filter	see table "Substrates"
622	ca. 330	ca. 370	ca. 415	weak yellow filter, anti-reflection treated	see table "Substrates"



6.3 Grey and Amber tinted Absorption Filters for the Visible Region

Application: Optical filters with low spectral effect.

Type	mean visible transmission [%]	Main Characteristics	Max. Dimensions * [mm]
631	~ 15	transmission increasing with λ, low reflection	250 × 300
632	~ 40	lighter grey filter	250 × 300
633	~ 25	darker grey filter	250 × 300



* Larger sizes on request.

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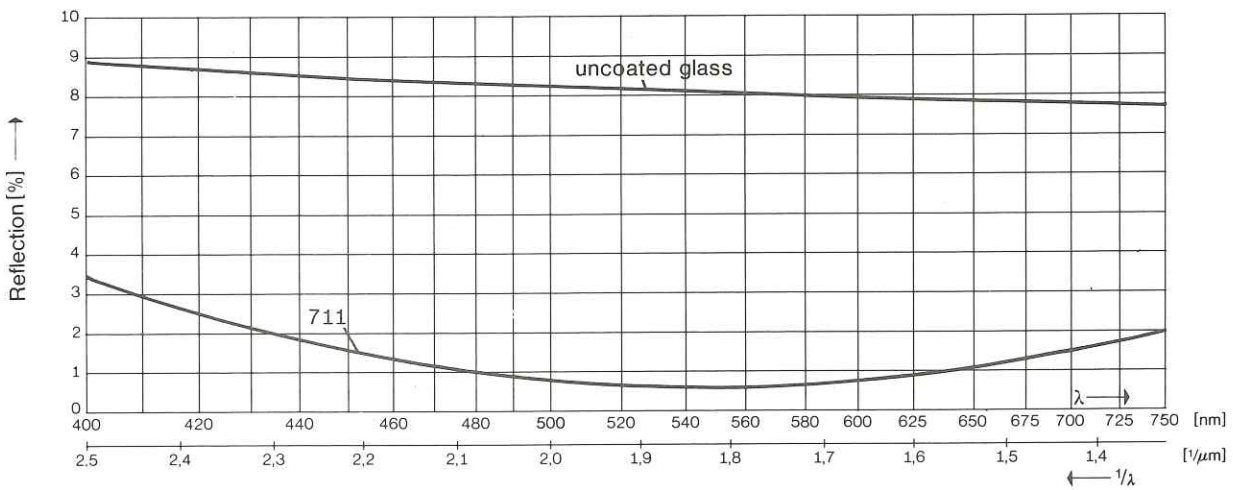
7. Anti-Reflection Coated Glasses

7.1 High Transmission Coatings

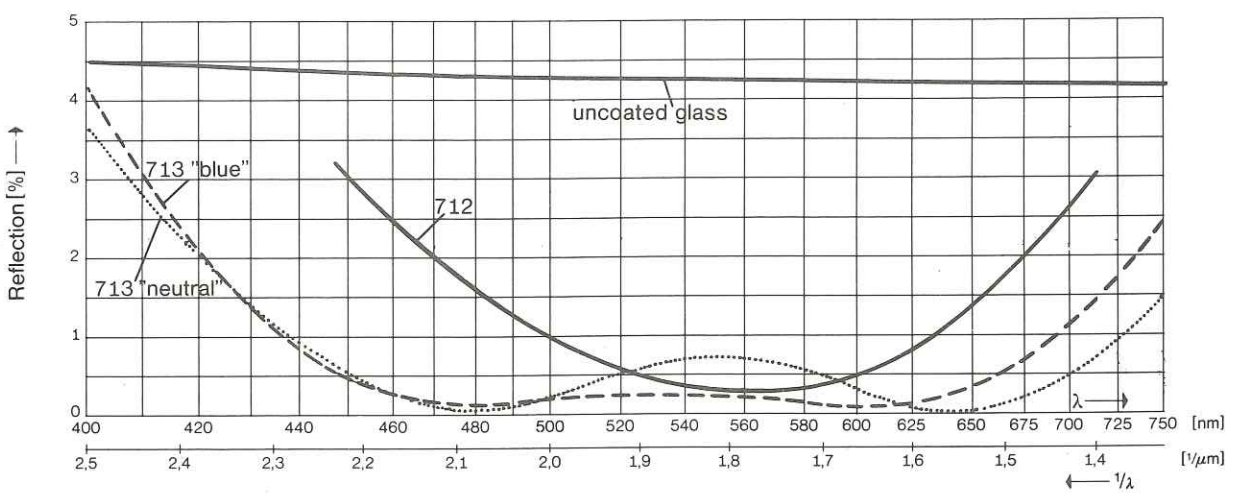
According to the refractive index of the glass, different coatings are used for the anti-reflection treatment. A triple layer coating is particularly suitable for the glasses mentioned in the table "Substrates".

Applications: Low reflection cover glasses for instruments, pictures, display cases a.s.o.; special treatment of highly refractive glasses to improve light transmission (e.g. radiation shielding windows).

Type	Type of Coating	Max. Dimensions [mm]
711	Single layer coating for glasses with refractive index > 1,60 (e.g. radiation shielding glasses)	on request



712	Double layer coating for plate glass, thickness > 10 mm	abt. 1300 × 1000
713	Triple layer coating for flat glass, thickness ≤ 10 mm**	abt. 2300 × 1250



** The residual spectral reflection is approximately within the limit curves of "blue" and "neutral".

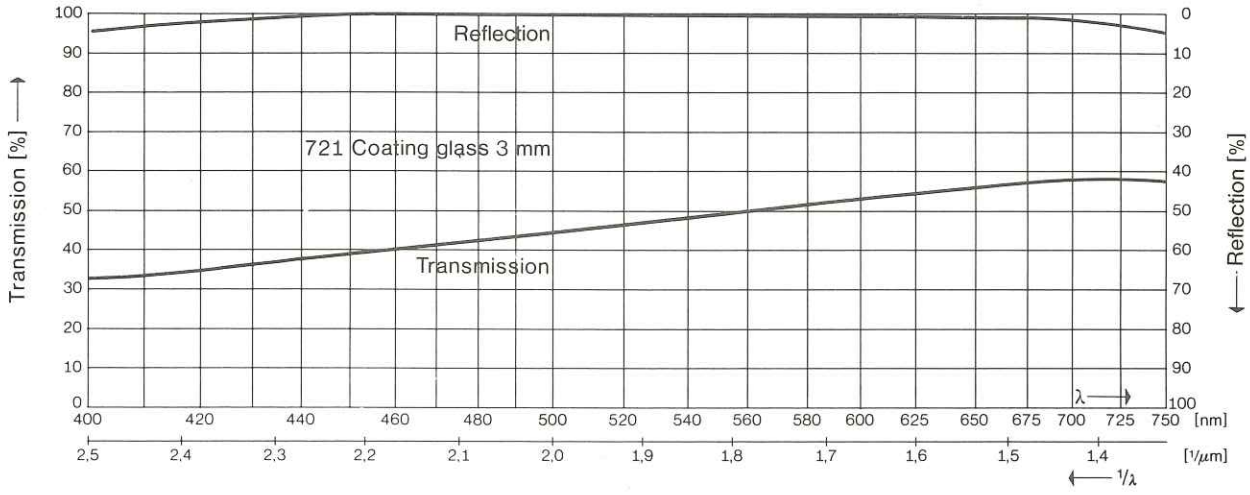
Symbols:
λ = wavelength [nm or μm]

7.2 Coatings with reduced Light Transmission

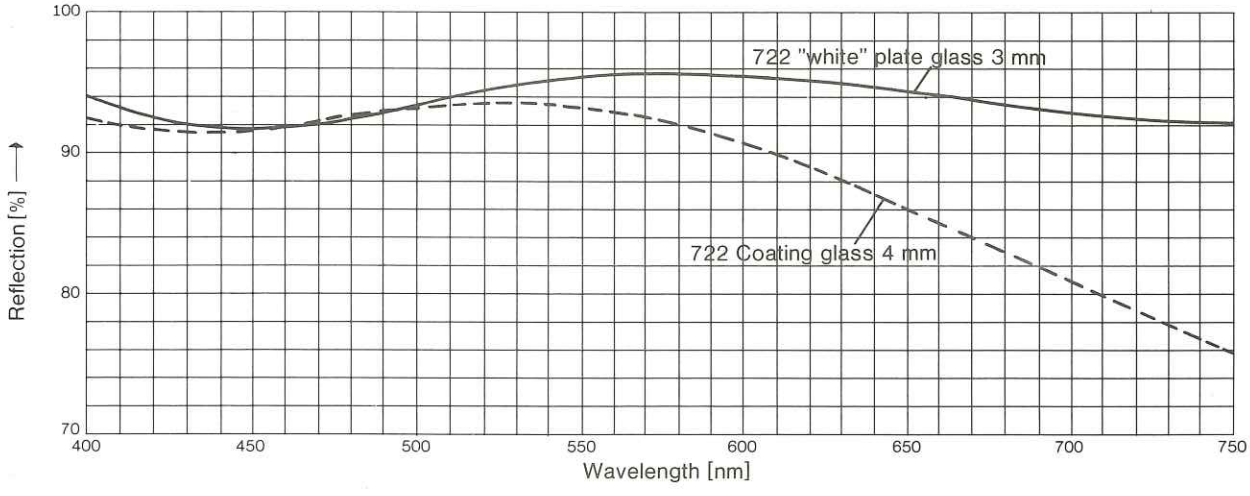
Ghost free back surface coated mirrors.

Substrates: Preferably coating glass or plate glass.

Type	Type of Coating	Average light transmission	Max. Dimensions [mm]
721	Absorbing multilayer coating	abt. 50%	on request



722	Ghost free mirror: Plate glass with triple-layer anti-reflection coating; rear side silvered and lacquer protected	----	1800 × 1000



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8. Glasses with Transparent Conductive Coatings

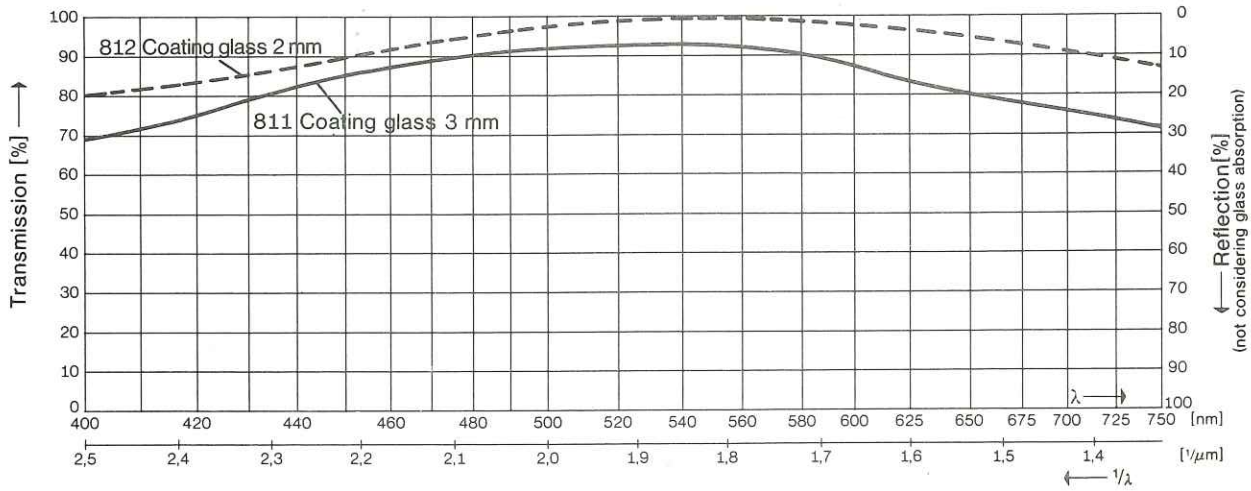
8.1 Anti-static Coatings with High Light Transmission

Semi-conductive oxide layers, with additional anti-reflection coatings for type no. 812. Coatings on both sides. The surface resistance mentioned refers to measurements on square faces with the electrodes applied on two opposite sides.

Substrates: Tempax® * glass (fire polished or mechanically polished), white plate glass B 270 (minimum thickness 3 mm), coating glass, cover glass D 263.

Applications: Conduction of electro-static charges on instrument and cover glasses, in particular for sensitive meters.

Type	Surface resistance [Ω/□]	Average light transmission [%]	Max. Dimensions ** [mm]
811	10^4 to 10^5	~ 90	500 × 500
812	10^6 to 10^8	≳ 95	500 × 500



* Tempax® = sheet glass, see leaflet no. 8801.

** Special dimensions upon request

Symbols: λ = wavelength [nm or μm]

8.2 Highly Conductive Coatings

Semi-conductive metal-oxide layers for conductivities and charges higher than with types 811 and 812, applied on one side (anti-reflection coated for visible light for types 824, 825 and 826).

The coatings are resistant up to 300 °C and show only minor changes of their properties in this temperature range.

All types exhibit reflectivity for infrared wavelengths above 2 µm which increases with conductivity.

Substrates: see 8.1.

Applications: Electro-optical elements, heated windows, heat protection and insulation.

Coating types 824, 825 and 826, have higher light transmission and can more easily be etched; therefore, they are particularly suitable for applications in photoresist techniques.

Type	Surface resistance [Ω/□]	Average light transmission [%]	Max. Dimensions [mm]
821	≲ 200	70	500 × 500
822	200 to 500	70 to 75	500 × 500
823	500 to 1500	75 to 80	500 × 500
824	≲ 200	80 to 90	500 × 500
825	200 to 500	80 to 90	500 × 500
826	500 to 1500	80 to 90	500 × 500

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Glass Substrates

The properties and dimensions of the glass substrates mainly employed are given in the table below.

The preferred substrates for the various types of coatings are mentioned in the data sheets. Under certain conditions and upon request it is also possible to coat other special glasses and glasses sent by customers. However, for glasses sent in for coating we cannot assume the risk of breakage.

The designations given below in the column "Surface" are to be understood as follows:

natural (fire polished)
= machine drawn flat glass without any mechanical surface treatment

mechanically polished
= glasses ground and polished on both sides

float polished
= plate glass produced in a special float process and without any mechanical surface treatment.

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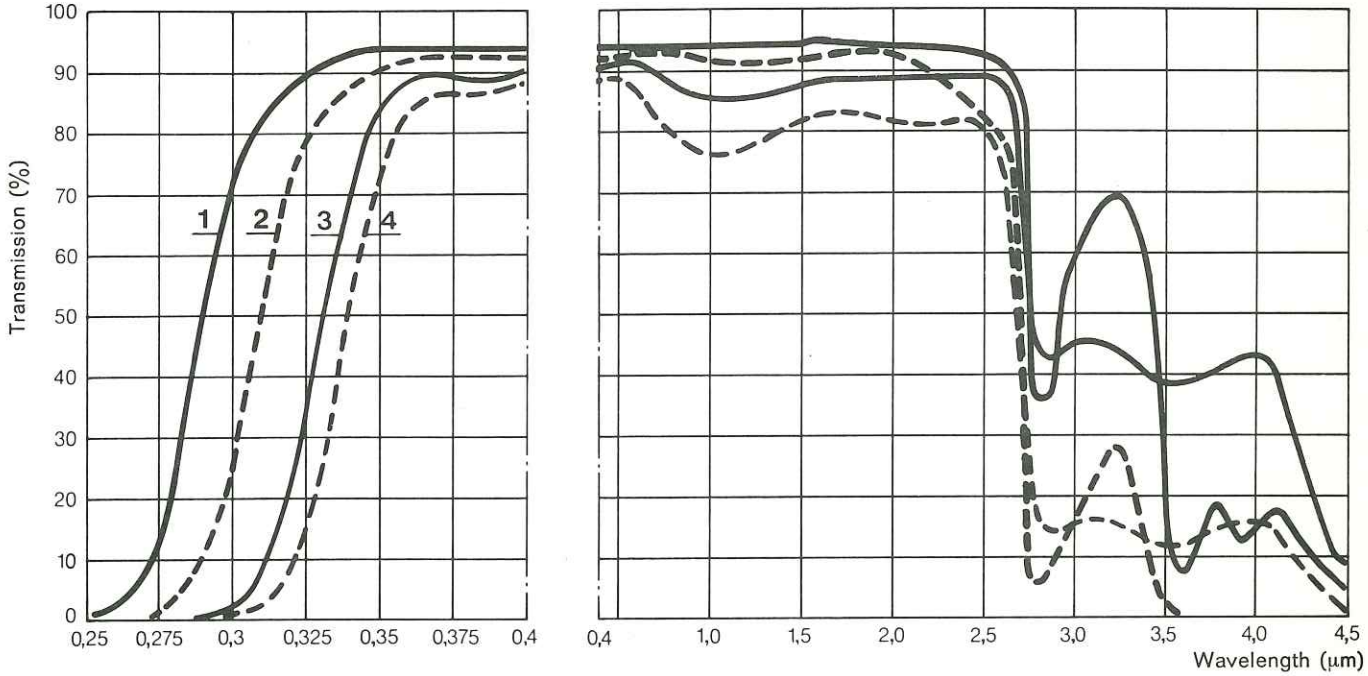
Glass Type	Surface	Thermal Expansion Coefficient ($\alpha \cdot 10^7/°C$)	Thickness (mm)	Maximum Dimension * (mm)	In Diagram Transmission Curve No.
Tempax ®** sheet glass (heat resistant)	natural (fire polished)	32	0.8–1.2 1.3–1.7 1.8–2.2 2.0–2.5 2.5–3.0 3.0–3.6 3.5–4.0 3.6–4.4 4.5–5.5	in general up to 780 x 550 larger sizes on request	1 / 2
dto.	mechanically polished	32	1–4	up to 750 x 500	1 / 2
Coating Glass (selected machine drawn glass)	natural (fire polished)	85–90	0.8–3.8 commercial sheet glasses	up to 1500 x 800	3
Plate Glass (Float Glass)	float polished	85–90	5–12	up to 1500 x 800	4
Plate Glass, Colourless ("white plate glass B 270")	mechanically polished	ca. 90	1–5	up to 600 x 500 larger sizes on request	5
Heat Absorbing Plate Glass	mechanically polished	ca. 90	up to 5	up to 1500 x 800	6 / 7
Fused Silica	mechanically polished	ca. 5	Glass types and dimensions on request		
Tubing of DURAN or Fused Silica	fire polished	32 5	Glass types and dimensions on request		

* Some filter types can only be made in smaller sizes (data sheets).

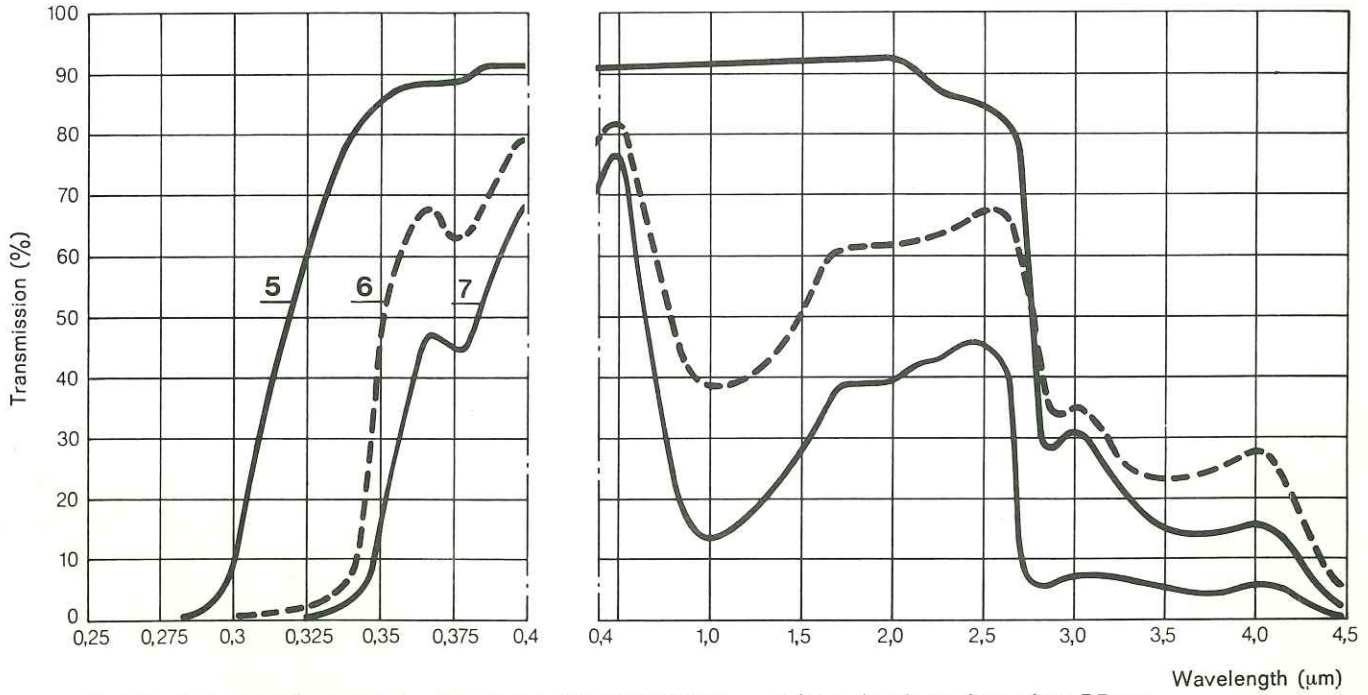
** For Tempax® see leaflet no. 8801.

Transmission Curves

The spectral transmittance of the various glasses is shown in the following diagrams:



1 TEMPAX® 1 mm **2** TEMPAX® 4 mm **3** coating glass **4** plate glass



5 plate glass, colourless, 3 mm **6** heat absorbing sheet glass **7** heat absorbing sheet glass 5,7 mm

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